
**Impact of *Deepwater Horizon* Oil Spill
Response Activities on Sand Beaches:
Literature Review-Based Evaluation of
Injury to Beach-Nesting Birds**
Technical Report
Draft

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August 31, 2015

SC13992

DWH-AR0124513

1. Introduction and Summary

Sand beaches were oiled extensively during the *Deepwater Horizon* (DWH) oil spill, and the level of response activities undertaken to clean up the oil was unprecedented. Cleanup crews spent many tens of thousands of hours on beaches, manually searching for and removing oil with hand-held tools and using large, heavy equipment – such as excavators and sand-sifting mechanized equipment – to dig through the sand and remove buried oil. In addition to the direct adverse effects of oiling, these response activities led to ancillary injuries to sand beach habitat and to the biological resources that use these beaches.

Sand beaches on Louisiana's coastal and barrier islands serve many ecological functions; key among these is providing nesting habitat for many bird species, including several state species of greatest conservation need (LDWF, 2015). Many of these species are also sensitive to human disturbance, particularly during nesting season (Anderson and Keith, 1980; Safina and Burger, 1983; Novick, 1996; Lafferty et al., 2006; McGowan and Simons, 2006). The spill occurred at the beginning of the nesting season (April–July) for many bird species (Shields, 2014; Burger, 2015), and the extended cleanup activities that occurred following the spill also overlapped with nesting seasons in subsequent years. Accordingly, our analysis of the impacts of response activities on sand beach habitat focused on evaluating the impact to beach-nesting birds. The analysis was based on a review of the literature on the impacts of human disturbance to birds during nesting seasons and a comparison to cleanup activities documented in DWH response records.

Our analysis showed that all types of response activities adversely affected nesting birds, from highly invasive activities using heavy equipment, to removal activities using hand-held tools. Even what might be considered “light” manual response activities on beaches, such as crews walking the beach searching for oil, likely had significant adverse impacts on bird nesting because of the sensitivity of nesting birds to human disturbance.

The remainder of this report is structured as follows:

- ▶ Section 2 provides background information, including the ecological importance of Louisiana's sand beaches and an overview of the response activities that took place on these sand beaches
- ▶ Section 3 describes our assessment approach, which was to determine the impacts of response activities on beach-nesting birds by comparing the types of response activities that occurred to analogous human disturbances reported in the literature
- ▶ Section 4 describes the results of our analysis, including the results of reviewing the literature and the response records review
- ▶ Finally, Section 5 provides a summary.

2. Background Information

2.1 Louisiana's Sand Beaches as Bird-Nesting Habitat

Sand beaches in Louisiana that were oiled as a result of the DWH oil spill are mainly found along the outer, sea-facing side of the islands that rim Louisiana's coastline, as well as along passes and spits in the Mississippi Delta (Figure 1). Much of Louisiana's sand beach shoreline falls within state and federal protected habitats, including state Wildlife Management Areas and Refuges, such as the Isles Dernieres Barrier Islands Refuge, and National Wildlife Refuges (NWRs), such as the Breton NWR in the Chandeleur Island Chain. According to Rice (2012), 94% of Louisiana's sand shoreline remains undeveloped, natural habitat.

The sand and marsh shoreline of coastal Louisiana is one of the most important and productive nesting areas in North America for many species of birds, and much of coastal Louisiana is classified by the National Audubon Society as a Globally Important Bird Area (Audubon, 2015). For many of the birds that rely on Louisiana's sand beaches and marshes, it is the combined presence and connectivity of these two habitat types, in close proximity to one another, which makes the shoreline so ideal. The birds nest on the beaches and feed on invertebrates and fishes in the nearby marshes (Gosselink, 1984; Caffey et al., 2000). Furthermore, a strong attraction of many of these beaches is their remoteness – they offer bird nesting habitat that is largely free from predators. The remoteness also minimizes disturbance from many anthropogenic sources, such as vehicular and foot traffic, domestic cats and dogs, industry, and others (Greer et al., 1988; Visser et al., 2005).

2.2 Oiling and Response Activities on Sand Beaches

Louisiana sand beaches were first oiled in early May 2010, when oil reached the Chandeleur Islands. Ultimately, more than 180 miles of sand beach shoreline in Louisiana was oiled (Michel et al., 2015). Virtually all of the islands in Terrebonne Bay, Barataria Bay, and the Chandeleur Islands experienced some degree of oiling as a result of the spill, and much of it was heavy oiling (Figure 2). Oil on these sand beaches was stranded in discontinuous waves over a period of months. Multiple drivers pushed the oil on to the beaches, including wide tidal ranges, storms, and hurricanes. Consequently, the oil became incorporated into the sediments across a wide swath of the affected beaches. Once stranded, the oil often was buried under sand, only to be later re-exposed and remobilized by the next wave or storm event. The stranding, burial, remobilization, re-exposure, and re-oiling occurred in temporal and spatial patterns that were difficult to predict, which increased the complexity of the cleanup efforts.

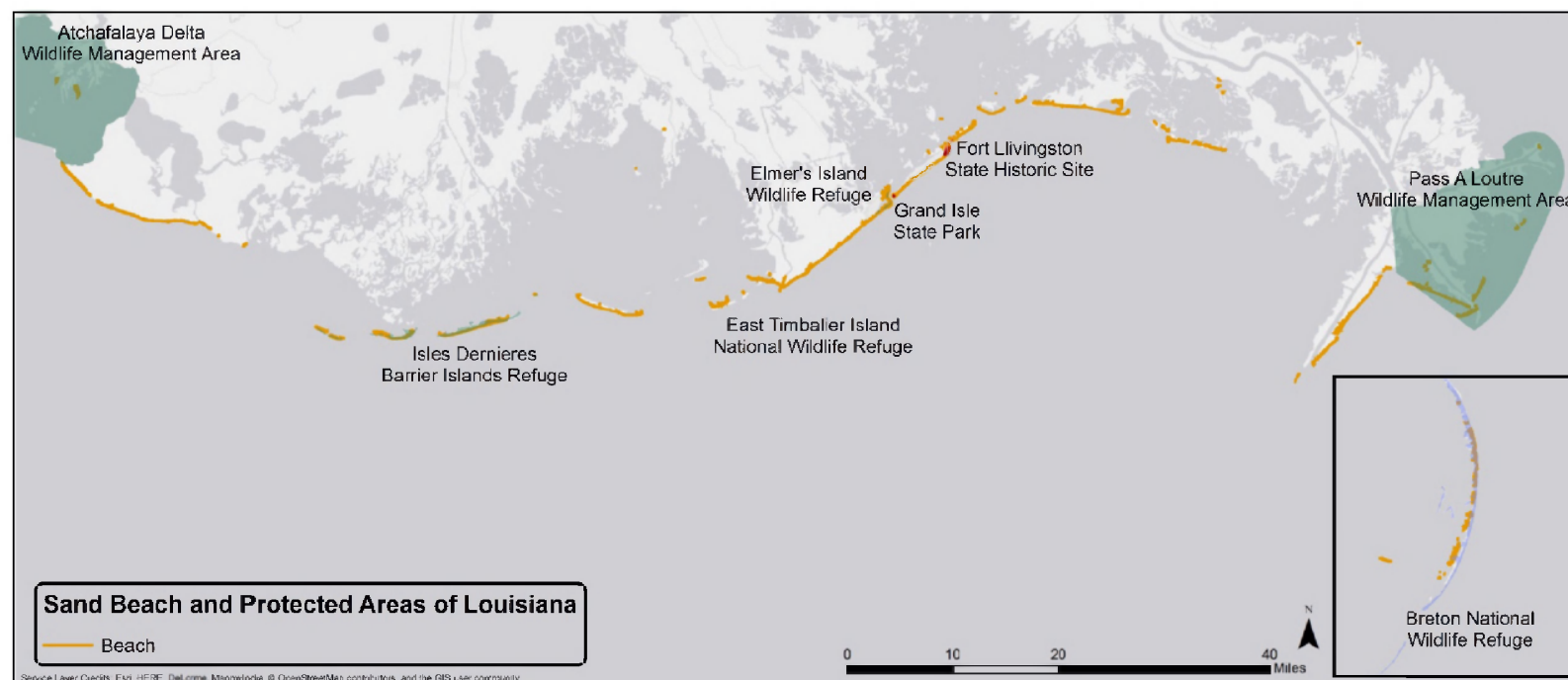


Figure 1. Sand beaches (orange) along Louisiana's Gulf of Mexico coastline, showing state and federally managed lands (green). Purple: NWR; green: Wildlife Management Area; red: state park.

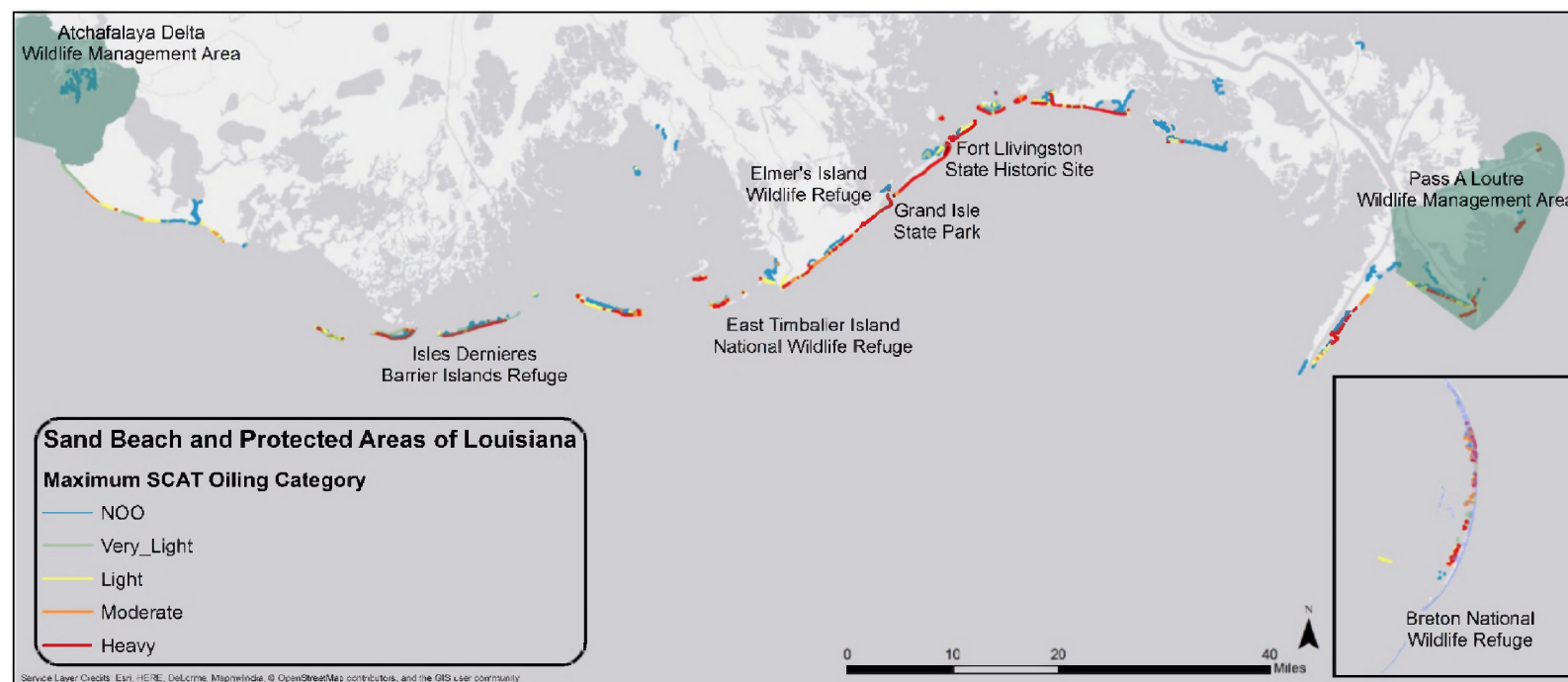


Figure 2. Maximum Shoreline Cleanup Assessment Techniques (SCAT) oiling of sand beaches. Most of the sand beaches in Louisiana were heavily oiled. NOO = no observable oil.

Shoreline cleanup activities began in the summer of 2010. Because of the unprecedented amount of oil that was stranded on sand beaches and the complicated temporal and spatial patterns of oiling, cleanup on sand beaches required several years of effort. In contrast to the other affected states, Louisiana suffered by far the most prolonged and extensive cleanup. The cleanup activities in Texas were completed by August 2010. In Florida, Alabama, and Mississippi, cleanup was completed in June 2013, three years after the spill. In Louisiana, shoreline cleanup operations on sand beaches extended for even longer. Until March 2014, there were still 7 miles of sand beach under active monitoring in Louisiana, and removal activities have continued into 2015. Of note, some of Louisiana's most important island nesting habitat was disturbed over these years of sand beach cleanup, including Queen Bess Island, Cat Island, and Raccoon Island.

The scale and magnitude of the sand beach cleanup effort is illustrated by the amount of oily waste materials removed from sand beaches. Table 1 and Figure 3 provide a summary of total oily materials removed from sand beaches, by state. The sources of the data presented in Table 1 for Alabama, Mississippi, and Florida are summarized in Michel et al. (2015). We compiled data from additional sources for the State of Louisiana. Specifically, we extracted data from the daily response records (referred to as "209 reports") that had not previously been compiled to determine pounds of oily materials removed from Louisiana beaches for the first year after the spill.

Table 1. Total oily materials removed from sand beach habitat, by state, 2010–2015

State	Oiled materials removed July 2010–March 2015 (lbs)
Louisiana ^a	121,784,710
Mississippi ^b	567,750
Alabama ^b	891,200
Florida ^b	74,070
a. Compiled from the response records – daily 209 reports.	
b. Michel et al., 2015.	

Shoreline treatments used to remove oil and oiled materials (sand, beach wrack, and other oiled natural debris) ranged from manual techniques involving crews of workers digging out oil with hand-held tools (Figure 4) to the use of large excavators, amphibious equipment, and sand-sifting equipment (Figure 5).

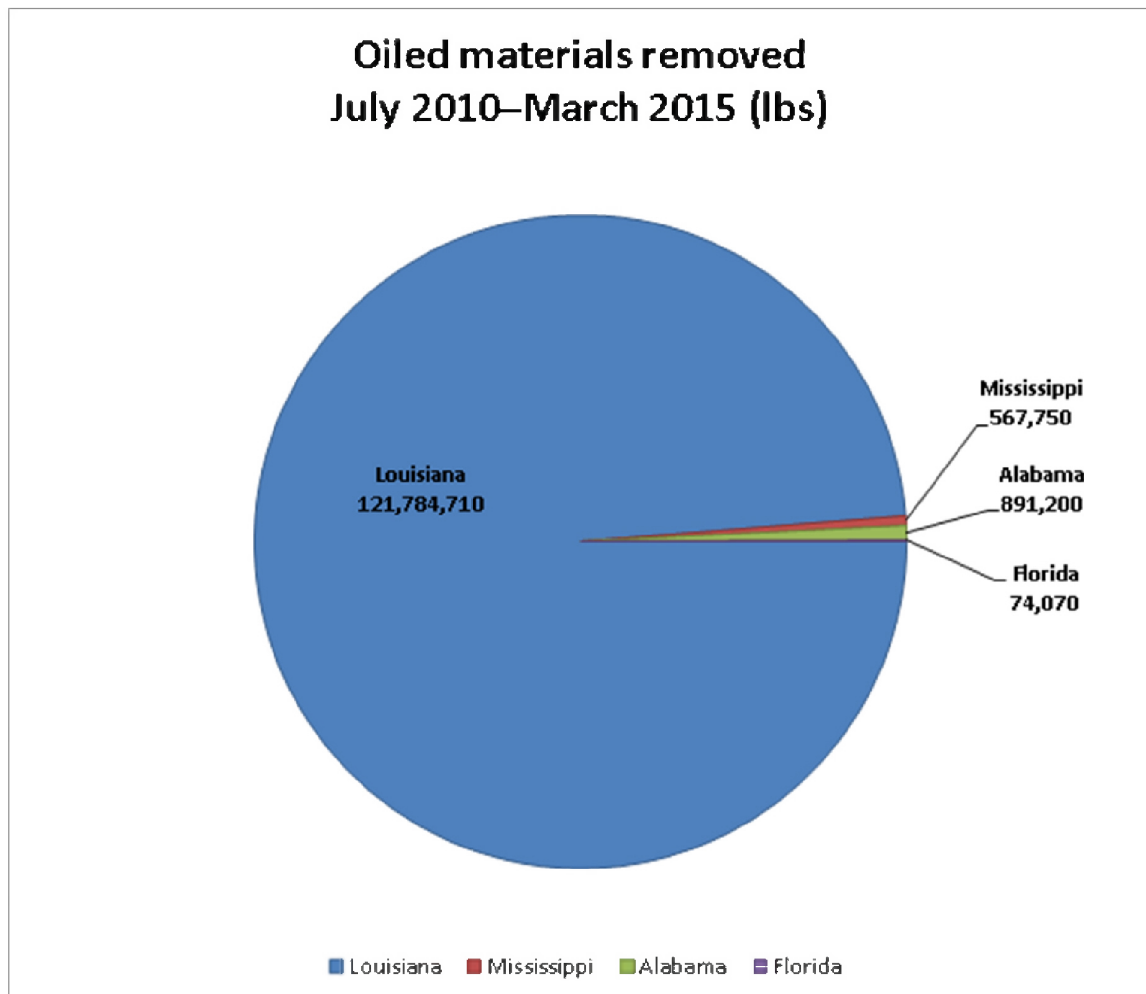


Figure 3. Total oily materials removed from sand beach habitat, by state, 2010–2015; compiled from response records. Data sources provided in Table 1.

Beach cleanup typically involved field teams initially visiting locations in search of oil as a part of the SCAT surveys, after which Shoreline Treatment Recommendation reports (STRs) were generated. Shoreline cleanup operation crews were then deployed to clean up oiled shorelines in accordance with the STRs, which required up to months of effort. SCAT field teams were then deployed to determine that No Further Treatment (NFT) was achieved. If the initial cleanup effort did not achieve this determination, shoreline crews returned to complete the cleanup. This entire process would be repeated each time additional oil became stranded on the beach, and/or buried oil was re-exposed by waves (Santner et al., 2011; USCG, 2011a; Michel et al., 2013).



Figure 4. Workers engaged in “manual” removal of oil. Manual removal of buried mats after removal of clean overburden using mechanical equipment, Grand Terre II, Louisiana, December 15, 2010. Note the small excavator and utility task vehicle (UTV) in the left of the photograph. The excavator was used to scrape the overburden. UTVs were used for hauling oiled materials. Vehicles were also used to transport workers to cleanup sites. Virtually all “manual” cleanup activities included the use of vehicles.

Specifically, the types of response activities that occurred on sand beaches included:

- ▶ SCAT and Rapid Assessment team shoreline characterization visits
- ▶ Manual treatment by response crews using hand-held tools
- ▶ Augering to search for buried oil
- ▶ Sifting to separate the oil from sand and remove it
- ▶ Tilling to break up the oil and expose it to air, with the anticipation that this would accelerate biodegradation
- ▶ Excavating and dredging to remove large volumes of oiled sediments for sifting or disposal.

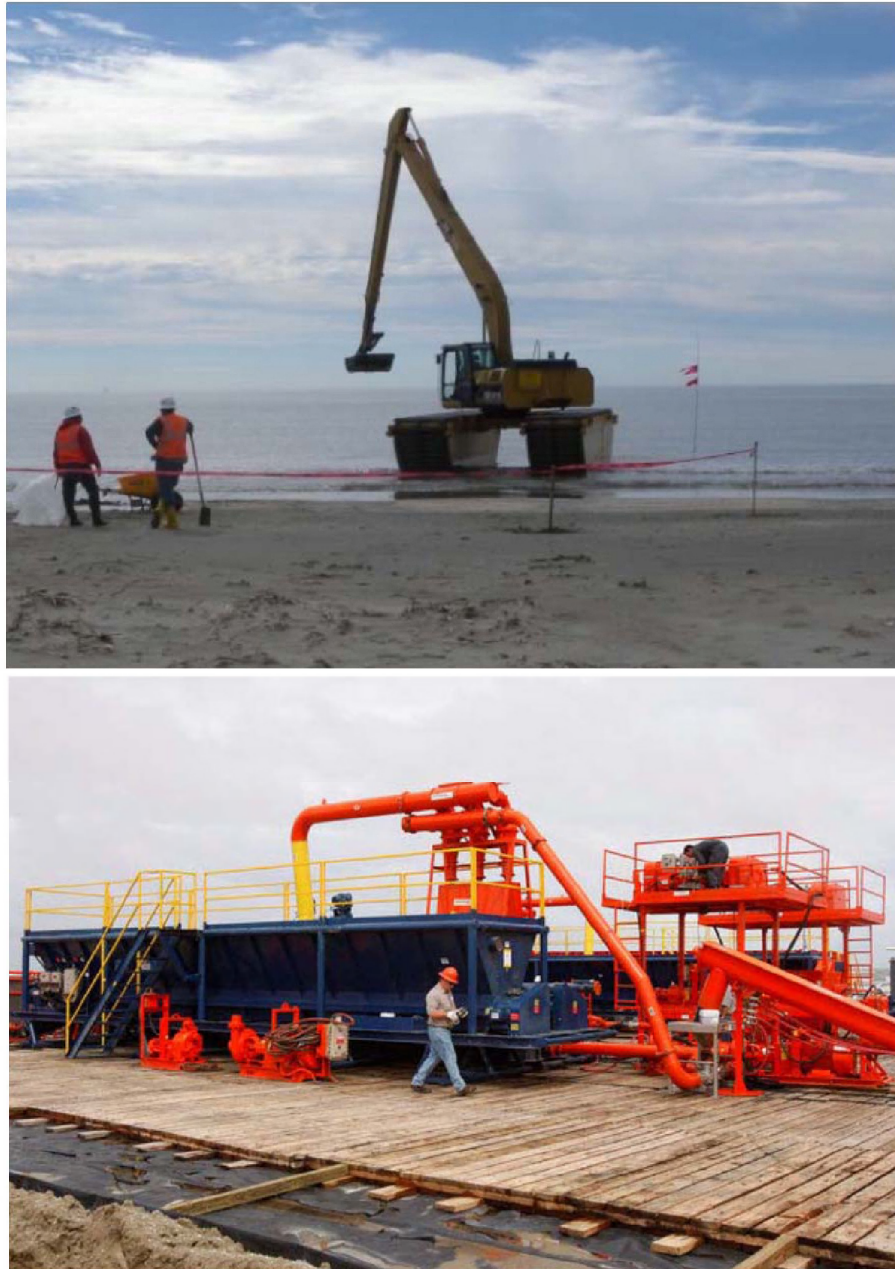


Figure 5. Use of heavy equipment during cleanup activities on sand beaches. Top photo: “Marsh buggy” amphibious vehicle removing oil mat, Bayou Chaland, Louisiana, January 27, 2011; bottom photo: stationary sand sifting equipment, Grand Isle, Louisiana, July 9, 2010.

Source: USCG, 2011b.

Beginning in June 2011, the United States Coast Guard (which was in charge of response operations) began tracking cleanup activities by individual beach segments (i.e., unit lengths of sand beach shoreline, defined for the purposes of cleanup activities). Before June 2011, records were only kept at a Parish or basin level. During just the period between June 2011 and September 2013, response teams visited many Louisiana beach habitats hundreds of times, including several that required over 500 response crew visits to address oil in a little over two years (Figure 6). Even this is an underestimate, because it does not include the initial SCAT and Rapid Assessment site visits that documented the presence of oil, nor does it account for boat traffic disturbances, or other response impacts such as the stranding of boom up on sand beaches, which likely acted as physical barrier to small chicks attempting to traverse the beach (see Figure 2.15 in DWH Trustees, 2015, Chapter 2, Incident Description). As described in Section 4.3 below, for some bird species, even a single disturbance during nesting season can result in the loss of the entire reproductive season.

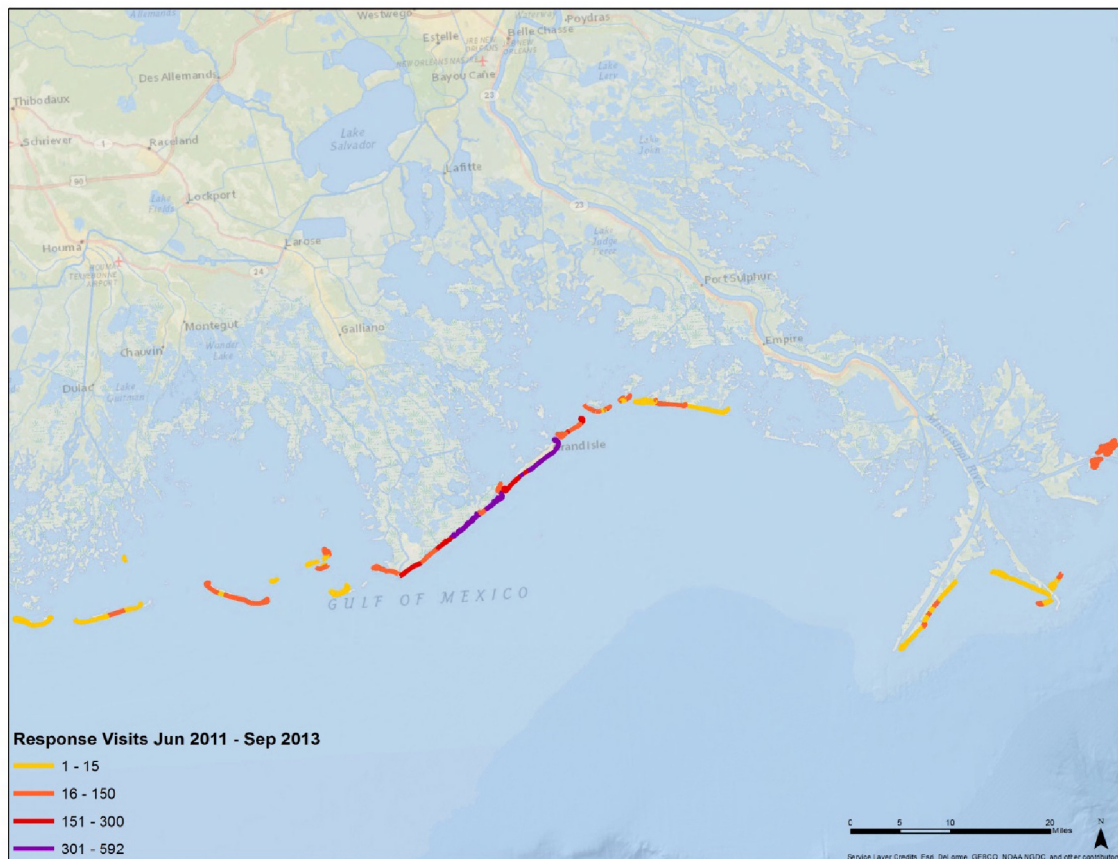


Figure 6. Total response crew visits to Louisiana beaches between June 2011 and September 2013. These numbers do not include initial SCAT and Rapid Assessment site visits.

3. Assessment Approach

We evaluated the impacts of response activities to beach-nesting birds by comparing the types of response activities that occurred on sand beaches to information in the scientific literature concerning the impact of comparable disturbances to birds nesting on beaches. In this analysis, we considered the type, duration, and frequency of the human activities, focusing on eight bird species (see box). We selected these particular species because there was information available in the literature on their nesting behaviors and on the effects of human disturbance on nesting. We also selected them because they are all state “species of greatest conservation need” that nest on Louisiana beaches in the spring and summer (LDWF, 2015).

Louisiana beach-nesting bird species included in our analysis were:

- ▶ Snowy Plover
- ▶ American Oystercatcher
- ▶ Gull-Billed Tern
- ▶ Black Skimmer
- ▶ Wilson’s Plover
- ▶ Brown Pelican
- ▶ Sandwich Tern
- ▶ Least Tern

Specifically, our approach to assessing the effects of response activities on these birds was as follows:

- ▶ First, we compiled information from the literature on the types of disturbances that adversely affect the nesting of these species of birds. We wished to answer the question, *Which of the response activities that took place would be considered a disturbance?* We were specifically interested in whether response activities that might otherwise be considered “minor” or “low impact” might in fact have an adverse effect on beach-nesting birds.
- ▶ Next, we developed a conservative estimate of the duration of a disturbance that could result in a nest failure. We did this by using equations from the literature to estimate the time required for an unattended egg’s temperature to exceed levels that would cause embryonic death. We then compared this duration to available records on the duration of response activities on sand beaches. Note that the calculated duration is a conservative estimate of the time required for nest failure because other impacts, such as nest depredation, can occur much more quickly, essentially as soon as a nest is left unattended.
- ▶ We then compiled information from the literature on the frequency of disturbances that could result in nesting failure and the loss of a reproductive season. We analyzed available information on the frequency of response visits to Louisiana beaches.

The results of our analysis are described below.

4. Results

In this section, we provide a summary of our review of the literature on beach-nesting birds and our analysis of the DWH spill response records.

4.1 Evaluation of Human Disturbances

We conducted a literature review on human-related disturbances that can adversely affect bird nesting on sand beaches. This review revealed that disturbances that may seem “minor” can result in significant impacts to birds, including nest failure. Pedestrians walking past nests, boats driving by beaches, and vehicles driven on beaches have all been shown to be associated with decreased nesting success (Table 2), where “nesting success” is defined as the number of nests that produce viable fledglings. Specific examples of the types of impacts associated with these disturbances include, but are not limited to:

- ▶ Increased egg mortality, including direct destruction of eggs in nests by foot/vehicular traffic
- ▶ Increased chick mortality, including chicks run over or found dead in tire tracks
- ▶ Reduced number of young birds successfully leaving the nest (i.e., fledging success)
- ▶ Nest and colony site abandonment
- ▶ Reduced parental time attending nests, enabling increased predation or destruction of eggs.

Many of the activities summarized in Table 2, including pedestrian, vehicular, and boat traffic, are comparable to the least intrusive of the response activities that occurred on Louisiana sand beaches, such as crews patrolling beaches looking for oil, and crews being transported by UTVs to and from manual beach cleanup sites. Therefore, based on our review of this literature, we concluded that even the most minor response activities would have had the potential to adversely affect birds nesting on sand beaches, including nest failure.

Table 2. Summary of the impacts of human disturbance on birds during nesting

Species	Type of human disturbance	Impact on birds	References
American Oystercatcher	Human activity [pedestrian traffic, vehicle use, all-terrain vehicles (ATVs), camping]	<ul style="list-style-type: none"> ▶ Egg mortality increased in areas with high human-use activity. ▶ Most egg and hatchling mortalities occurred during weekends, and human activity on weekends was approximately double that of weekdays. ▶ 17% of hatchlings tracked during the study were run over by off-road vehicles (ORVs) and found dead in tire tracks. 	Novick, 1996
	Powerboats, personal watercraft, picnickers, anglers, and domestic pets	<ul style="list-style-type: none"> ▶ Nesting success was much higher on undisturbed islands (73%) compared to islands regularly used for human recreation (33%). ▶ Human disturbance resulted in nest abandonment and depredation. 	Toland, 1999
	ATV, ORV, and pedestrian traffic	<ul style="list-style-type: none"> ▶ Reduced time incubating (90% at undisturbed vs. 82% at disturbed nests). ▶ Increased number of trips to and from the nest (2.25 trips/hour at undisturbed nest vs. 3.66 trips/hour at all other nests). 	McGowan and Simons, 2006
	Pedestrian, boat, and vehicle traffic	<ul style="list-style-type: none"> ▶ Nesting success was much higher where humans were not allowed access (80%) compared to where human recreation was allowed (0%). ▶ Adult birds abandoned their nests as a result of the recreational disturbances. 	Sabine et al., 2006
Black Skimmer; mixed species colony	Researchers checking nests	<ul style="list-style-type: none"> ▶ Research visits had adverse effects on colony-nesting success, with more pronounced effects with more frequent visits. ▶ Daily researcher visits reduced the number of nesting adults by 37% from initial, pre-disturbance numbers. ▶ Hatching rates were lower in colonies visited daily (76%) than in colonies visited weekly (90%). The relative proportion of chicks fledged per hatched egg was higher in colonies disturbed weekly than daily. 	Safina and Burger, 1983

Table 2. Summary of the impacts of human disturbance on birds during nesting

Species	Type of human disturbance	Impact on birds	References
Brown Pelican	Humans walking through nesting colonies	<ul style="list-style-type: none"> ▶ Following nest abandonment, immediate losses of eggs and young to predation and hyperthermia occurred in the summer heat. ▶ Adverse effects of disturbance were greatest early in breeding season with catastrophic losses from even a single disturbance event. 	Anderson and Keith, 1980
	Human camping near nesting colonies	<ul style="list-style-type: none"> ▶ Increased nest abandonment and decreased productivity (number of young per nesting attempt) after establishment of fishing camps below nesting colonies. ▶ Young per nest attempt decreased from 0.87 to 0.34 because of increased nest abandonment after establishment of fishing camps. 	Anderson, 1988
Least Tern	Vehicle traffic	<ul style="list-style-type: none"> ▶ Colonies abandoned sites after vehicle disturbances (average of seven disturbances per hour). ▶ Birds returned and the number of nests steadily increased each year after vehicular traffic was restricted. 	Cowgill, 1989
Snowy Plover	Vehicle traffic, animals, beach recreation	<ul style="list-style-type: none"> ▶ Chick mortality increased with increased human visitation. ▶ Approximately twice as many chicks were lost during weekend days (409 cars/day average) compared to weekdays (84 cars/day average). 	Ruhlen et al., 2003
	Vehicle traffic, animals, beach recreation	<ul style="list-style-type: none"> ▶ Before protection, plovers did not breed at Coal Oil Point; subsequent to restricting human pedestrian access, plovers bred in increasing numbers each year and had high success fledging their young. 	Lafferty et al., 2006

In summary, wherever there was overlap between nesting habitat and response activity, there was likely some degree of injury to birds on sand beaches. Figure 7 provides an illustrative example of the overlap between the locations of colony nesting birds (including four of the species in our analysis – Brown Pelican, Black Skimmer, Least Tern, and Sandwich Tern) and response activities on sand beaches in Barataria Bay for the 2011 nesting season (April–July 2011). This example presents only the minimum overlap between response activities and nesting locations: First, as noted above, this dataset does not include initial SCAT visits to search for oil. Second, it does not explicitly account for the disturbance of boat traffic. Third, this example only shows the overlap of response activities with colony-nesting birds, and does not include locations for solitary nesters – such as American Oystercatcher, Snowy Plover, and Wilson’s Plover – which also nest on Louisiana sand beaches [e.g., see Johnson (2014) for information on Wilson’s Plover]. Even with these caveats, it is clear that response activities occurred in close proximity to nesting colonial bird habitat (Figure 7).

4.2 Response Visit Duration

The severity of the injury to nesting birds is likely a function of the duration and frequency of the disturbances within any given breeding season. In this section, we examine the duration of response-activity disturbances.

We first compiled information from the literature on bird-nesting behavior of the eight target species discussed previously. All eight of the bird species are tenacious nest attenders, seldom leaving their nests during daylight hours under normal circumstances (Table 3). This is likely out of necessity, both to keep the eggs protected from predation and to keep them cool from the summer heat; it is logical to therefore infer that even a short absence from the nest would have adverse consequences to nesting success.

If a disturbance causes adult birds to leave their nests, the unattended nests are vulnerable to predation, physical crushing by humans on foot or in vehicles, and exposure to solar radiation and overheating, potentially followed by embryonic death. Predation and crushing could occur at any time after the adult birds leave their nests. We assumed that nest failure caused by overheating would require the longest time. Thus, to conservatively estimate the duration of a response visit that would result in a nest failure, we calculated the time required for an exposed egg to overheat sufficiently to cause embryonic death.

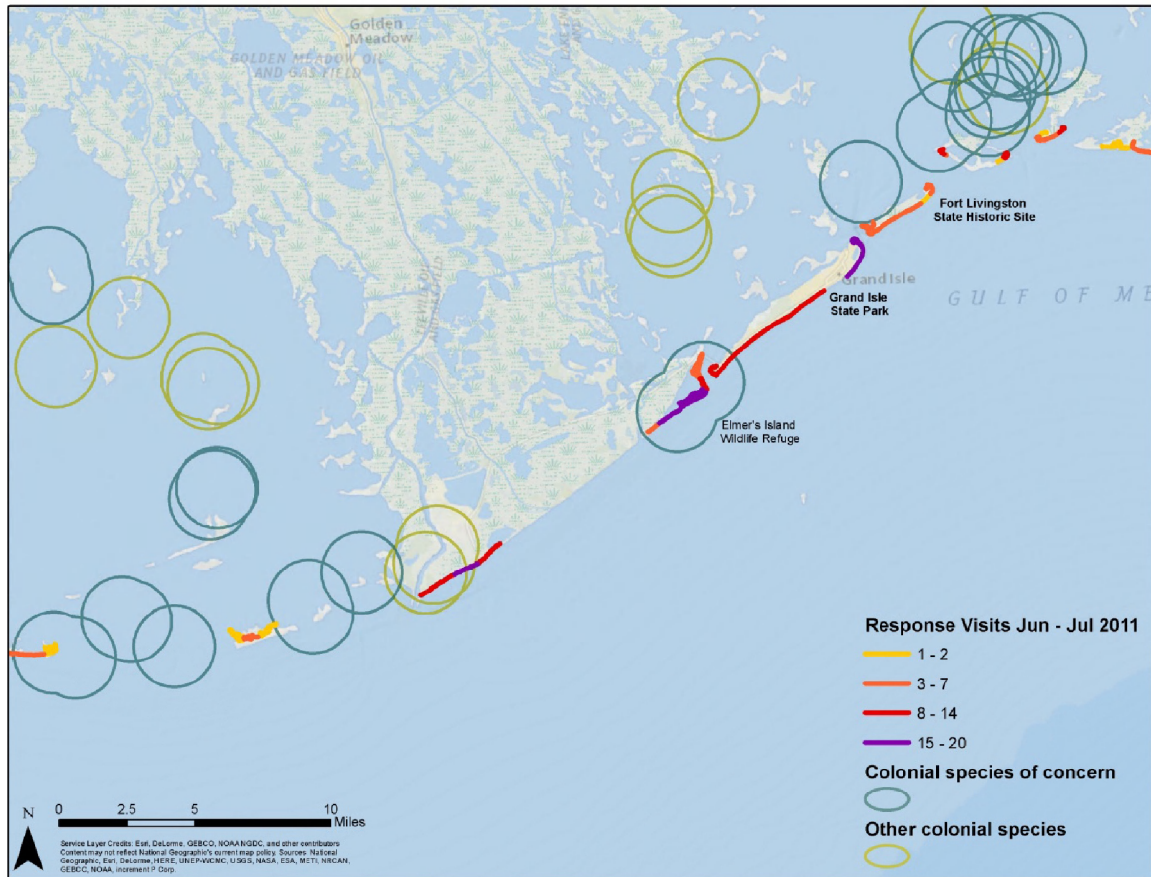


Figure 7. Illustrative example of the proximity of response activities (other than initial SCAT visits) to colonial bird nesting locations on sand beaches in Barataria Bay. State species of greatest conservation need in these colonies include Brown Pelican, Black Skimmer, Least Tern, and Sandwich Tern; figure does not show solitary nesters. Nesting season is typically April–July. However, we only show June–July 2011 response visits because that is the time period for which data on the number of response visits are available. Colony locations between 2001 and 2011 are shown.

Data source: Louisiana Natural Heritage Program.

Table 3. Life history information for birds that breed on Louisiana beaches in April through July

Species	Solitary (S) or colonial (C) nester	Single (SB), double (DB), or triple (TB) broods	Attempts to re-nest after nest failure?	Maximum re-attempts after first nest failure	Interval between re-attempts	Nest attentiveness information (during daylight hours)	References
Snowy Plover	S	TB	Yes	2	2 to 9 days	91% of the time by either parent	Page et al., 2009
American Oystercatcher	S	SB ¹	Yes ¹	6, but 1 most common ^{1, 2}	9 to 26 days (average 14) ^{1, 2}	90% of the time by either parent ³	1. Nol and Humphrey, 2012 2. Nol, 1989 3. McGowan and Simons, 2006
Gull-Billed Tern	C	SB	Yes	At least 1	NA	100% of the time during early incubation; 98% of entire incubation period	Molina et al., 2014
Black Skimmer	C	SB	Yes	3	NA	100% of the time by either parent, especially on hot afternoons	Gochfeld and Burger, 1994
Wilson's Plover	S	SB (DB very rare) ¹	Yes ^{1, 2}	7 ²	5 to 13 days (average 7.6) ²	76–92% of the time; varies according to ambient temperature ¹	1. Corbat and Bergstrom., 2000 2. Bergstrom, 1988
Brown Pelican	C	SB	Rare ^{1, 2}	1 attempt ² ; rare, not verified in the wild ¹	NA	One parent always present ¹	1. Shields, 2014 2. Schreiber, 1979
Sandwich Tern	C	SB ¹	Yes, but only early in the season ¹	1 attempt, if nest lost early in the season ¹	NA	Eggs consistently incubated when nest is established near other species' nests ²	1. Shealer, 1999 2. Langham, 1974
Least Tern	C	SB	Yes	3	4 to 30 days	One parent always present	Thompson et al., 1997

Superscripts refer to references listed in the same row.

NA = information not readily available in the literature.

We used a published exponential regression equation to estimate the time for an unattended egg to reach sufficient temperatures to cause death. This equation relates air and ground temperatures to egg temperatures and incorporates multiple sources of heat gain on an egg, the predominant one being direct solar radiation, given a starting egg temperature and an egg thermal constant (Westmoreland et al., 2007). We computed the thermal constants of eggs of different masses using another published equation that provides a relationship between egg mass and egg thermal constants (Turner, 1985). In general, because smaller eggs have lower thermal constants (and higher surface area to volume ratios), egg temperatures increase with decreasing egg size for a given ambient temperature.

Normal incubation temperatures for birds tend to range between 30°C and 40°C, and lethal temperature across bird embryos can be assumed to be > 45°C (Webb, 1987). Therefore, we used 45°C as the threshold to determine the time required to compromise an egg's vitality, and we assumed a starting egg temperature of 31°C. Based on the equation from Westmoreland et al. (2007), an egg that weighs 4 grams would exceed normal incubation temperatures in less than 30 minutes of full-sun exposure and would reach lethal temperatures within 1.5 hours (Figure 8). This is the egg size of most of the birds included in our study, including Wilson's and Snowy Plovers, the tern species, and American Oystercatchers. Note that the temperatures we used in our calculations are conservative, and if the starting egg temperature was in fact higher than 31°C, and/or mortality was reached before 45°C, the time required for embryonic death would be shorter.

Information on the duration of response visits to Louisiana sand beaches was recorded beginning in June 2011, and records are available until September 2013 (Table 4). Fifty-seven percent of sand beach response visits during this period were longer than 30 minutes, and 21% were longer than 1.5 hours (Table 4). Thus, a substantial proportion of sand beach response visits were of sufficient duration during this time period to result in embryonic overheating and death, if the adult birds were flushed from their nests and stayed away during the disturbance.

We conclude that a response visit of any duration that resulted in adult birds flushing from the nest could be sufficient to result in nest failure from predation or crushing. Furthermore, a substantial proportion of the visits were of sufficient duration to result in embryonic death because of eggs overheating.

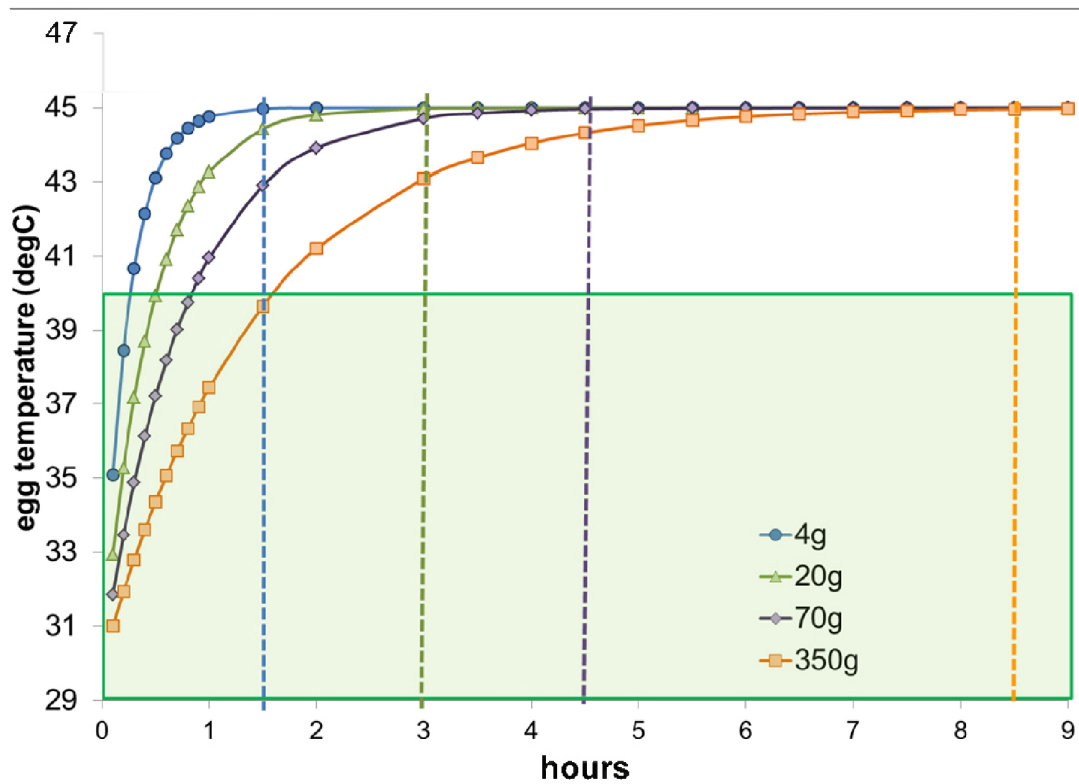


Figure 8. Time required for eggs of different masses to reach 45°C when exposed to solar radiation; 45°C is the temperature at which embryonic death occurs. The curves were derived based on an equation published by Westmoreland et al. (2007). This graph shows that a 4-gram egg would exceed “normal” temperature ranges (i.e., rise above 39.5°C) in less than 30 minutes, and would reach 45°C after 1.5 hours of exposure to solar radiation, resulting in embryonic death.

Table 4. Number of response visits to Louisiana sand beaches that occurred during nesting seasons in 2011, 2012, and 2013, by duration of visit

Duration of visit	< 30 min	30 min–1.5 hrs	1.5 hrs–4.5 hrs	> 4.5 hrs
Number of response visits	1,847	1,509	504	407

4.3 Response Visit Frequency

We also evaluated the impact of the frequency and the interval of time between response visits on bird nesting. Some studies have reported on the relationship between the frequency of disturbances during nesting season and nesting failure, and this relationship is highly species-dependent. For example, Safina and Burger (1983) reported that both daily and weekly visits had an impact on Black Skimmer nesting success. By contrast, Anderson and Keith (1980) reported catastrophic nest failure in Brown Pelican colonies after a single human disturbance during nesting season (see Table 2).

The variable relationship between the frequency of response visits and the severity of their impact may reflect species-specific nesting behavior. Although some species, such as Wilson's Plover and Black Skimmer, may re-attempt to nest multiple times after a nest failure, many species do not. For example, American Oystercatcher, Snowy Plover, and Brown Pelican may only re-attempt to nest once or twice – or not at all – after a nest failure (Table 3). Furthermore, studies have shown that subsequent nesting attempts after a failed nest may have fewer eggs and higher nest failure (Nol and Humphrey, 2012). Therefore, a small number of response visits to a beach could result in the loss of the entire nesting season for some bird species, if the timing coincided with their nesting and the disturbance resulted in nest abandonment.

There was a wide range in the frequency of response visits to the beaches in Louisiana during the nesting season in 2011, 2012, and 2013 (the years for which these data are available). Figures 9–11 provide illustrative examples of the frequency and temporal interval between response visits for three beaches in Louisiana: Grand Terre II, Timbalier, and Elmer's islands, respectively. We found little available information about the interval of time required for different bird species to re-attempt nesting after a nest failure, but the few data reported in the literature indicate there is a relatively wide range. As noted above, some birds, such as the Brown Pelican, may not re-attempt at all. American Oystercatchers and Least Terns may not attempt to re-establish a nest for several days or even up to a month, and Wilson's Plover may take up to two weeks. For many other species, this information simply is not known (Table 3).

Given the range in both response visit intervals and the range in bird nesting re-attempt intervals, there was likely a range in the success of any re-nesting attempts after an initial nest failure caused by a response visit on Louisiana beaches. For example, Grand Terre II Island (Figure 9) was visited every few days between May and June 2011, and it is likely that any attempt to re-establish a nest during this period would have been interrupted. By contrast, intervals between visits in 2012 were a month or longer, and thus there may have been sufficient time to allow for a successful re-attempt for birds such as American Oystercatchers, Wilson's Plovers, and Least Terns. However, the subsequent site visits could have resulted in failure of the subsequent nesting attempts, if they coincided with the second nesting attempt.

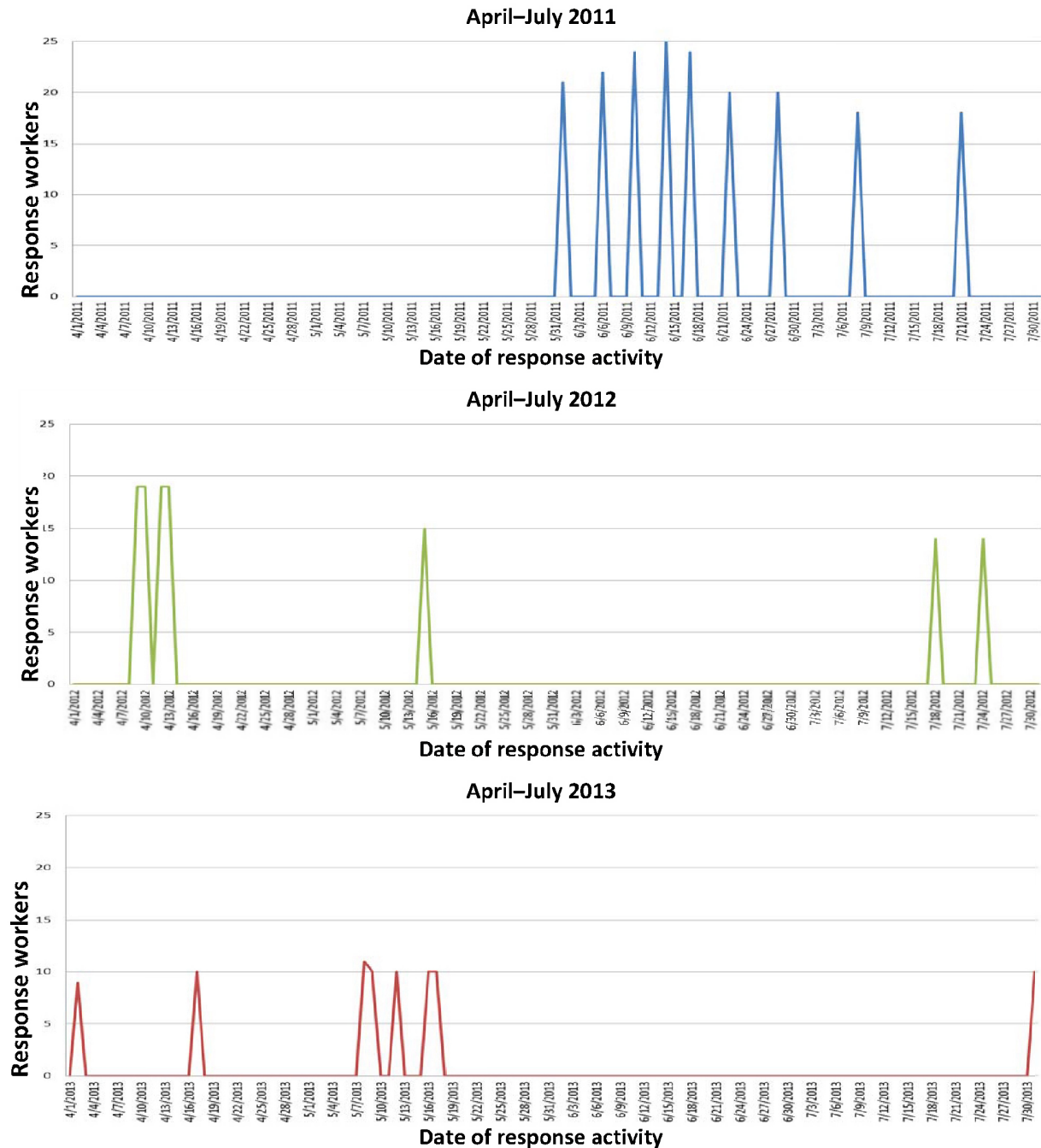


Figure 9. Response visits to Grand Terre II Island during the 2011, 2012, and 2013 nesting seasons.

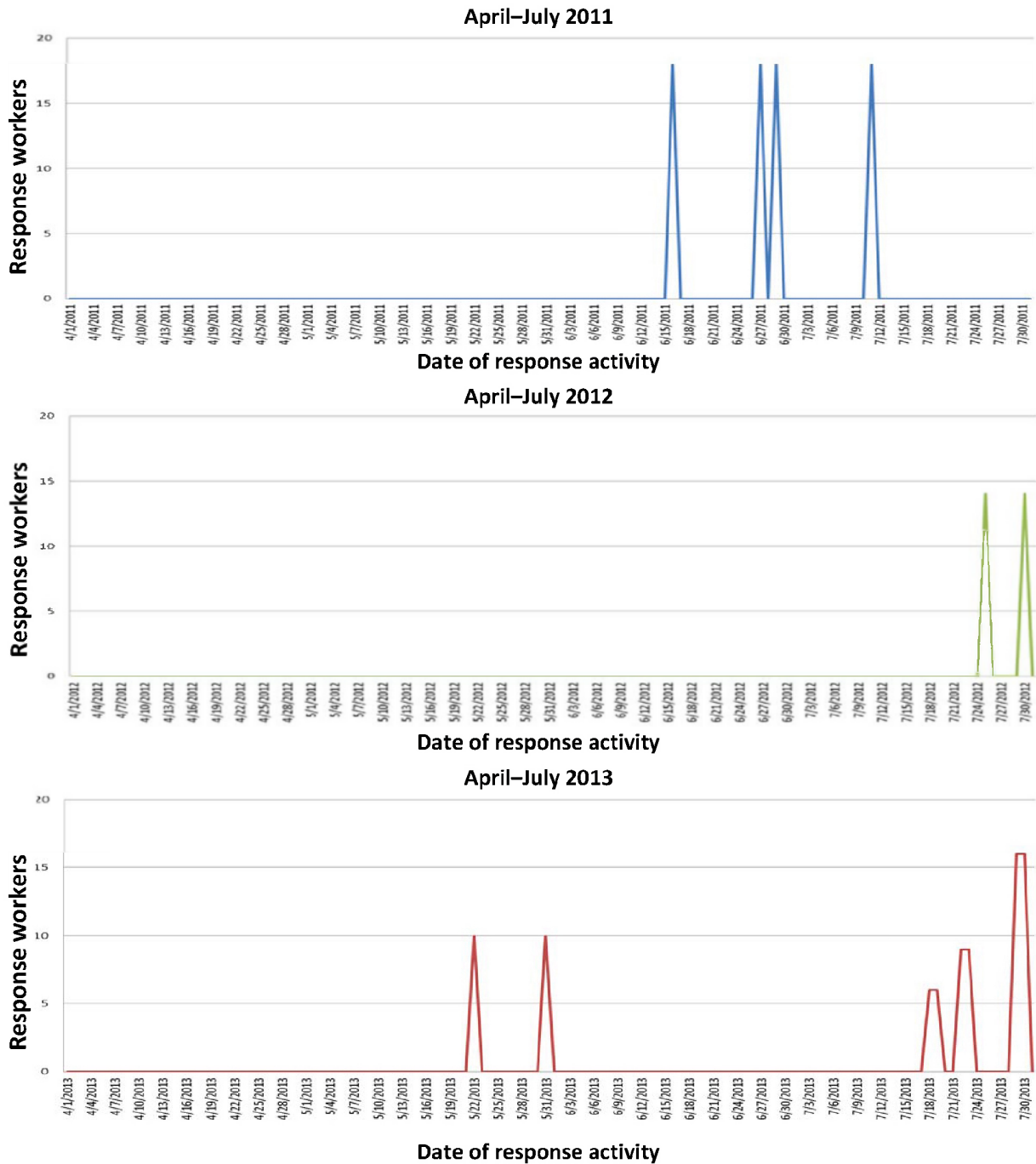


Figure 10. Response visits to Timbalier Island during the 2011, 2012, and 2013 nesting seasons.

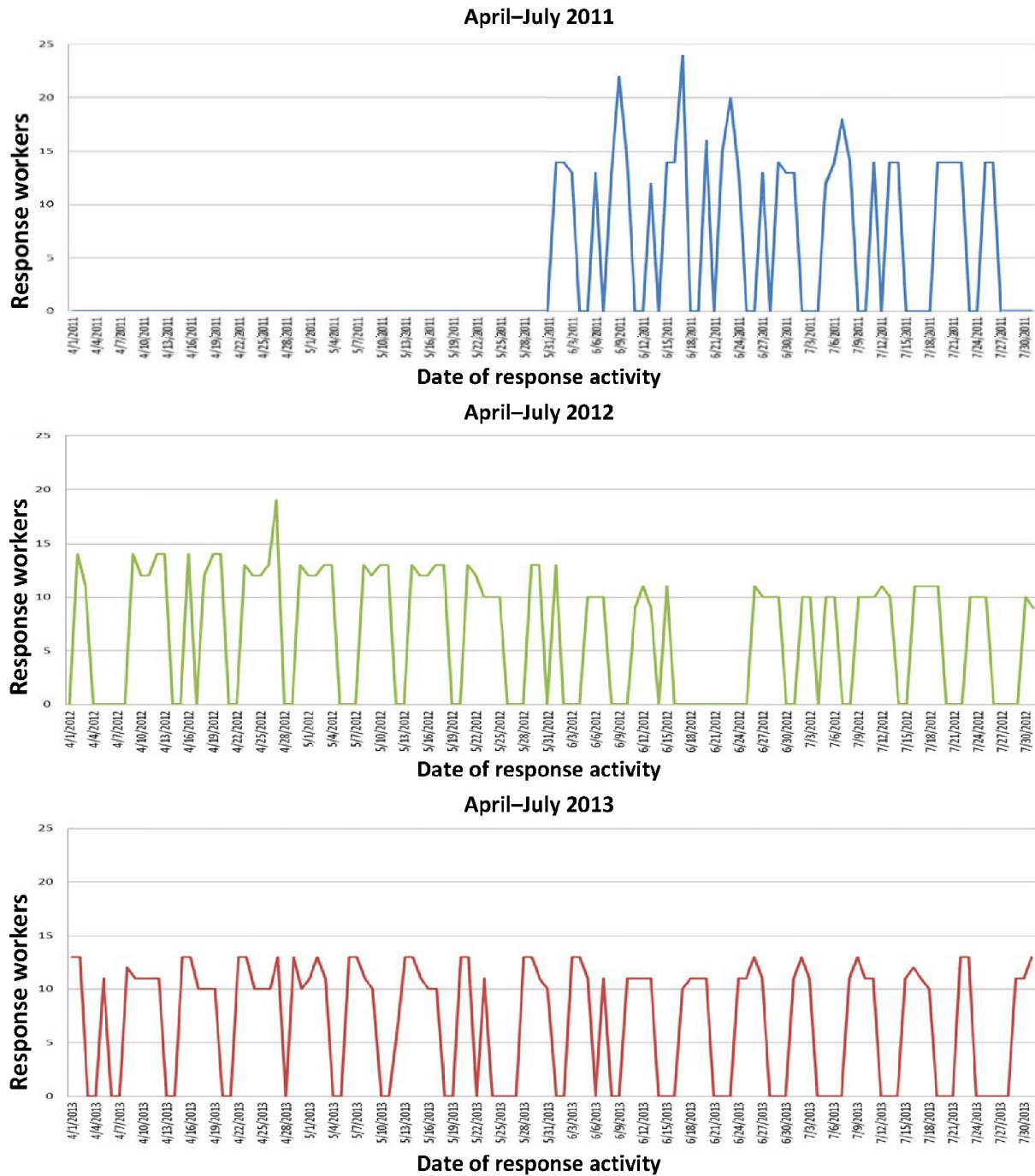


Figure 11. Response visits to Elmer's Island during the 2011, 2012, and 2013 nesting seasons.

Visits to Elmer's Island (Figure 11) were nearly constant over all three nesting seasons for which data are available. It is unlikely that nesting birds were successful with that frequency of disturbance.

It is important to note that Figures 9–11 do not incorporate any disturbances caused by response vessels passing by the islands, and these could have also had an adverse impact on nesting (see Table 2). Nor does it incorporate non-response disturbances, such as visits by the media and government officials. It is also important to note that the data shown in Figures 9–11 do not include the 2010 nesting season. As noted above, response data were not recorded at this level of spatial detail during the first year of cleanup activities. However, cleanup that first year was the most intense of all years. Indeed, Johnson (2014, p. 3) reported that, based on personal observations, "In 2010, the BP DWH oil spill created a situation where beaches were impacted not only from oiling, but also the clean-up crews sent to remove oil. This led to a year of near complete reproductive failure for Least Terns (*Sterna antillarum*) on Grand Isle and locally elsewhere in southeastern Louisiana."

5. Summary

In summary, based on a review of the literature on the effects of human disturbance to nesting birds and an analysis of response records kept for Louisiana sand beaches, we determined that response activities would have had an adverse impact on the nesting success of birds that nest on Louisiana sand beaches. The types of disturbances that occurred, the duration of response visits, and the frequency of visits would have all resulted in possible nest failure.

Based on a comparison to human disturbances reported in the literature, even "minor" activities, such as patrolling beaches for oil and manual cleanup of oil using hand-held tools, likely had a significant negative effect on sand beach functionality as nesting habitat. Furthermore, the duration of response visits would have been sufficient to result in nest failure, from predation, crushing, or overheating. Eggs left unattended by a flushed adult in the spring/summer sun will overheat to temperatures sufficient to cause embryonic mortality in 1.5 hours or less.

Finally, even a small number of visits during the nesting season likely would have resulted in reproductive failure for species of birds such as Brown Pelicans and terns that are prone to nest abandonment when disturbed. Response teams visited some beaches, such as Elmer's Island and Grand Isle, nearly every day for multiple nesting seasons. In those locations, it is unlikely that any bird species would have been able to nest successfully during the DWH response.

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